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Station Paper No. 140 5a March 1962

3 Value Growth of Pine Pulpwood on the George Walton Experimental Forest

by

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INTRODUCTION

In order to maximize profit it is necessary that the grower of pine pulpwood not only retain the proper amount of growing stock but also select the proper trees to remove when thinning. Those trees not expected to earn their way over the next growth period should be harvested. To a considerable extent, therefore, profit maximization depends on the actions of the timber marker.

The financial maturity concept provides a method for selecting trees to retain as growing stock so as to maximize profits from timber growing. To apply this concept to timber marking decisions, it is necessary to determine and compare two factors, the alternative rate of return of the owner and the value growth rate of the timber. The alternative rate of return is the minimum rate, expressed in compound interest form, that the owner will accept on investments of equal risk.[2] This rate will vary considerably, depending on the individual owner's economic situation.

Value growth is the increase in value obtained by retaining a tree over an additional growth period. It is generally expressed as a compound interest rate based on the value of a combination of quantity and quality growth of growing stock for a given period of time. Financial maturity is reached when the tree's value growth rate expected over the future period is equal to the owner's alternative rate of return. Marking guides based on financial maturity are in demand because of the growing realization among forest owners that adequate profit must be forthcoming to justify increases in growing stock.

1/ This paper is based on research reported in a thesis submitted to the School of Forestry of Duke University in partial fulfillment of the requirements for the degree of Master of Forestry.

The George Walton Experimental Forest, located near Cordele, Georgia, is maintained by the Southeastern Forest Experiment Station in cooperation with Mr. Holt E. Walton.

2/ A discussion of the alternative rate of return and its determination may be found in: "Financial Maturity: A Guide to Profitable Timber Growing" by William A. Duerr, John Fedkiw, and Sam Guttenberg. U. S. Dept. Agr. Tech. Bul. 1146, 74 pp. 1956.

Of the two factors defining financial maturity, the value growth rate is the only one that can be quantified objectively and thus is susceptible to research. The other determinant, the alternative rate of return, cannot be fixed by anyone but the owner.

The first objective of the study described in this paper was to isolate recognizable tree characteristics that are useful indicators of the future value growth rate. A second objective was to demonstrate the application of financial maturity concepts to longleaf and slash pine pulpwood management.

THE STUDY AREA AND SCOPE

A study of pine pulpwood value growth was carried out in the summer of 1958 on the George Walton Experimental Forest in the middle coastal plain of Georgia. Much of the area was previously agricultural land, having been mostly cropped for cotton and peanuts. The topography is level to gently rolling, and soils are predominantly loamy sands with a sandy clay subsoil. Summers are hot and humid and the growing season quite long.

Pine stands under study were managed in even-aged groups. Past management was effected through a series of improvement cuts, each operation removing the poorest individuals. Stand health and vigor was improved by each of these cuts. It became increasingly necessary, however, to choose between trees of apparent equal silvicultural worth in timber marking operations. The point was reached, therefore, where financial guides to timber marking were needed.

Naturally regenerated pulpwood-sized stands of longleaf and slash pine were studied. Pulpwood value growth was studied from the viewpoint of a stumpage seller in order to develop marking rules useful in guiding thinning operations. No measure of quality growth was included because no price differential is paid for pulpwood quality. Two additional assumptions were made: (1) no change in pulpwood prices would occur during the growth period, and (2) a uniform price would be paid for all tracts, regardless of differences in logging costs. Under these conditions, value growth rate is identical to volume growth rate.[3]

Since the study was limited to the George Walton Experimental Forest, the results are directly applicable only to this area. They are useful, however, for comparative purposes throughout the longleaf-slash pine type in the middle coastal plain of Georgia.

3/ Most management costs are expended on a per-acre basis and will influence the length of rotation of the final crop trees. Such costs do not, however, enter into marking decisions in a thinning operation.

STUDY METHODS

The 5-year interval, 1953-57, was selected as the measured growth period. As a first step in development of value growth percents (value growth rate expressed as percent of capital value), volume growth rates were established for both species.

Study plots were purposively selected to sample the available range of ages, sites, and densities. Sampling was accomplished on temporary, circular one-fourth acre plots, with uniform stand and site conditions established after the stands had been selectively marked for cutting.

The study data were of two types: stand measurements, and individual sample tree measurements. Stand variables measured included stand density in 1953 (established by stand reconstruction techniques) and site index (50-year basis).

Sample trees were those marked for removal in a commercial pulpwood operation. The sample trees were all vigorous, comparable in age and size to trees retained in the stand, and in a round condition (i.e., had not been chipped for naval stores). Trees with a 1958 d.b.h. below 4.6 inches or a merchantable height of less than one 5-foot bolt were not sampled. Badly deformed or diseased trees and trees infested by insects or damaged by fire or lightning were not sampled, nor were isolated (wolf) or severely suppressed trees.

Sample tree data included past age, past merchantable height to both the 2-inch and 3-inch top limit d.i.b., and past diameter at breast height.[4] Crown class and crown ratio of each sample tree were noted. Past crown ratio was estimated by relating 1958 crown ratio to tree characteristics by multiple regression techniques, and inserting past known values of these tree characteristics into the regression equations to predict past crown ratios. Consistent with known patterns of development in southern pine, crown class was assumed to have remained the same over the 5-year growth period.

Taper measurements and increment borings were taken over the bole length of the felled sample trees. Volume growth was then calculated as the difference between past and present planimetered merchantable volume diagrams. Top diameter limits were the only merchantability restrictions imposed on trees in the analysis.

A total of 225 sample trees was measured on 34 plots. Of these sample trees, 146 were longleaf pine and 79 were slash pine. The number of sample trees measured per plot varied from 2 to 14, averaging 6.6.

4/ "Past" in this paper refers to the value of the characteristic at the beginning of the 5-year growth period (1953).

CUBIC-FOOT VOLUME GROWTH

Longleaf Pine

Analysis of the longleaf pine cubic-foot growth data yielded the following equations:5/ 6/

Top diameter 2.0 inches inside bark

$$G = -0.915365 + 0.005806\ [(D.b.h.)(CR)] + 0.000248\ [(SI)(CR)] + 0.303048\ [(D+C)-(I+S)]$$

The independent variables accounted for 78 percent of the variation around the mean and the standard error of estimate was 0.471 cubic foot.

Top diameter 3.0 inches inside bark

$$G = -0.868449 + 0.005744\ [(D.b.h.)(CR)] + 0.000247\ [(SI)(CR)] + 0.300461\ [(D+C)-(I+S)]$$

The independent variables accounted for 76 percent of the variation around the mean and the standard error of estimate was 0.494 cubic foot.

5/ Data were fitted to the form:

$$G = b_0 + b_1 (BA) + b_2 (SI) + b_3 (1/N) + b_4 (A) + b_5 [(BA)(A)] + b_6 [(SI)(A)] + b_7 (H) + b_8 (CR) + b_9 (D.b.h.) + b_{10} [(D.b.h.)(CR)] + b_{11} [(SI)(CR)] + b_{12} [(D+C)-(I+S)] + b_{13} [(D+I)-(C+S)] + b_{14} [(D+S)-(C+I)]$$

where

G = five-year merchantable volume growth (excluding bark), cubic feet
BA = stand basal area at the beginning of the growth period, square feet per acre
SI = site index (50-year basis), feet
N = number of trees (1-inch d.b.h. and over) per acre at the beginning of the growth period
A = age at the beginning of the growth period, years
H = merchantable height to 2-inch and 3-inch tops (inside bark) at the beginning of the growth period, feet
CR = crown ratio at the beginning of the growth period, percentage of total height in live crown
D.b.h. = diameter at breast height at the beginning of the growth period (outside bark), inches
D = dominant crown class
C = codominant crown class
I = intermediate crown class
S = suppressed crown class
$b_0, b_1 \ldots b_{14}$ = partial regression coefficients

6/ Values of the crown class comparison variables were derived for each tree by simply inserting a value of unity for the appropriate crown class, inserting zeros for remaining crown classes, and summing the expression.

Slash Pine

The slash pine cubic-foot growth data yielded the following equations:[7]

Top diameter 2.0 inches inside bark

$$G = 0.408181 + 0.007282\ [(D.b.h.)(CR)] - 0.212243\ (Av.\ Stand\ D.b.h.) + 0.180083\ [(D+C)-(I+S)] + 0.186319\ (D.b.h.)$$

The independent variables included in this equation accounted for 71 percent of the variation around the mean. The standard error of estimate was 0.482 cubic foot.

Top diameter 3.0 inches inside bark

$$G = 0.326468 + 0.007621\ [(D.b.h.)(CR)] - 0.220384\ (Av.\ Stand\ D.b.h.) + 0.190537\ [(D+C)-(I+S)] + 0.211590\ (D.b.h.)$$

The independent variables in the above equation accounted for 71 percent of the variation around the mean. The standard error of estimate was 0.506 cubic foot.

The range of data used to develop the above equations is presented in table 1.

Changes in growth rate attributable to the crown class variables indicate that as far as future merchantable cubic-foot volume growth is concerned it is quite important to recognize whether a tree is in the upper two or lower two crown classes. There was not, however, any significant difference found between the growth of dominant and codominant trees, or between intermediate and suppressed trees.

Table 1.--Range of 1953 data used in volume growth equations

Species	Basal area	Site index	Trees per acre	Age	Merchantable height to 2-inch top limit	Merchantable height to 3-inch top limit	Crown ratio	D.b.h.	Average d.b.h. of stand
	Sq. ft. per acre	Feet	Number	Years	Feet	Feet	Percent	Inches	Inches
Longleaf pine	9 to 124	53 to 101	92 to 1148	10 to 41	6 to 55	0 to 48	38 to 76	2.8 to 9.5	3.2 to 11.8
Slash pine	16 to 124	59 to 103	128 to 1148	7 to 32	2 to 62	0 to 58	26 to 57	2.0 to 10.8	2.3 to 10.9

7/ Two of the variables found to be significant in the slash pine analyses, 1/N and BA, were combined into a single variable, Average Stand D.b.h., and the analyses recomputed to shorten and simplify the resulting equations.

The equations indicate that merchantable cubic-foot volume growth increases as diameter at breast height, crown ratio, and crown class increase. For longleaf pine, growth also increases with increasing site indices. For slash pine, growth decreases as average stand diameter increases. These findings agree with what would be expected on the basis of present silvicultural knowledge.

The absence of site index as a significant variable in the slash pine equations is difficult to explain. Perhaps less variation in site quality in this species than in the longleaf pine sample is an explanation. Another consideration is that site index curves are not as dependable for younger age classes as for older ones. Slash pine site indices were based on an average age of 24.6 years, compared to 38.5 years for longleaf pine. Age likely did not occur as a variable in either set of equations because variation in age was small within species and age is correlated with diameter when density, site, and crown class are accounted for.

The longleaf pine sample adequately represented the range of ages, sizes, sites, and densities encountered in the study area, but the slash pine sample did not. The slash pine trees sampled were concentrated in the smaller size and younger age classes. It was desirable, of course, to sample trees which had not yet become merchantable for pulpwood at the beginning of the growth period in order to discover growth trends in the lower diameter and younger age classes.

The concentration of the slash pine data in the smaller size and younger age classes resulted mainly because the sampled classes were the only ones available during the period field work was in process. Also, it was difficult to secure adequate distribution of sample trees with regard to many of the variables employed in the growth function because the applicable values of the variables had to be derived employing stand and tree reconstruction techniques.

PULPWOOD VALUE GROWTH PERCENTS

Tables showing the value growth percents were constructed from merchantable volume growth equations (tables 2 to 9).

In order to convert volume growth to value growth percent it was necessary to solve the following formula for p:

$$(1+p)^n = \frac{Vn}{Vo}$$

where

p = value growth rate, percent
Vn = volume at the end of growth period, cubic feet
Vo = volume at the beginning of growth period, cubic feet
n = growth period, years.

Table 2.--Expected value growth percents for longleaf pine pulpwood over a 5-year period for dominant and codominant crown classes with a top diameter of 2.0 inches inside bark

D. b. h. (inches)	Crown ratio - percent				
	30	40	50	60	70
	- - - - - - Percent - - - - - -				
SITE INDEX 60					
4	8.7	13.5	17.7	21.3	24.6
5	5.6	8.5	11.2	13.7	15.9
6	4.3	6.4	8.4	10.3	12.0
7	3.5	5.3	6.8	8.3	9.8
8	3.1	4.4	5.8	7.0	8.2
9	2.7	3.9	5.0	6.1	7.2
SITE INDEX 70					
4	9.7	14.7	18.9	22.6	25.9
5	6.1	9.2	11.9	14.4	16.7
6	4.6	6.8	8.9	10.8	12.6
7	3.8	5.5	7.2	8.7	10.2
8	3.2	4.7	6.0	7.3	8.6
9	2.8	4.1	5.2	6.3	7.4
SITE INDEX 80					
4	10.7	15.8	20.1	23.9	27.2
5	6.6	9.8	12.6	15.2	17.6
6	5.0	7.2	9.4	11.3	13.2
7	4.0	5.8	7.5	9.1	10.6
8	3.4	4.9	6.3	7.6	8.9
9	3.0	4.2	5.4	6.6	7.7
SITE INDEX 90					
4	11.6	16.8	21.2	25.1	28.5
5	7.1	10.4	13.3	15.9	18.4
6	5.3	7.6	9.8	11.8	13.7
7	4.2	6.1	7.8	9.5	11.0
8	3.6	5.1	6.5	7.9	9.2
9	3.1	4.4	5.6	6.8	8.0

Table 3.--Expected value growth percents for longleaf pine pulpwood over a 5-year period for intermediate and suppressed crown classes with a top diameter of 2.0 inches inside bark

D. b. h. (inches)	Crown ratio - percent				
	30	40	50	60	70
	- - - - - - Percent - - - - - -				
SITE INDEX 60					
4	--	5.3	10.8	15.3	19.2
5	0.9	4.4	7.5	10.2	12.8
6	1.4	3.8	6.0	8.0	9.9
7	1.6	3.4	5.1	6.7	8.2
8	1.6	3.1	4.5	5.8	7.1
9	1.5	2.8	4.0	5.1	6.2
SITE INDEX 70					
4	--	6.9	12.3	16.9	20.8
5	1.5	5.1	8.3	11.1	13.7
6	1.8	4.2	6.5	8.6	10.5
7	1.8	3.7	5.4	7.1	8.6
8	1.8	3.3	4.7	6.1	7.4
9	1.7	3.0	4.2	5.4	6.5
SITE INDEX 80					
4	1.4	8.3	13.8	18.4	22.4
5	2.1	5.8	9.1	12.0	14.6
6	2.1	4.7	7.0	9.1	11.1
7	2.1	4.0	5.8	7.5	9.1
8	2.0	3.5	5.0	6.4	7.7
9	1.8	3.2	4.4	5.6	6.8
SITE INDEX 90					
4	2.8	9.7	15.2	19.8	23.8
5	2.7	6.5	9.8	12.8	15.5
6	2.5	5.1	7.5	9.7	11.7
7	2.3	4.3	6.2	7.9	9.5
8	2.1	3.8	5.3	6.7	8.1
9	2.0	3.3	4.6	5.8	7.0

Table 4.--Expected value growth percents for longleaf pine pulpwood over a 5-year period for dominant and codominant crown classes with a top diameter of 3.0 inches inside bark

D.b.h. (inches)	Crown ratio - percent				
	30	40	50	60	70
	- - - - - - Percent - - - - - -				
SITE INDEX 60					
4	13.5	19.8	25.0	29.5	33.4
5	6.8	10.1	13.0	15.7	18.2
6	4.8	7.1	9.2	11.1	13.0
7	3.8	5.6	7.2	8.7	10.2
8	3.2	4.6	6.0	7.2	8.4
9	2.8	4.0	5.1	6.2	7.3
SITE INDEX 70					
4	14.8	21.3	26.6	31.1	35.1
5	7.4	10.8	13.8	16.6	19.1
6	5.2	7.5	9.7	11.7	13.6
7	4.1	5.8	7.6	9.1	10.6
8	3.4	4.8	6.2	7.5	8.8
9	2.9	4.1	5.3	6.4	7.5
SITE INDEX 80					
4	16.1	22.6	28.0	32.6	36.7
5	8.0	11.5	14.6	17.4	20.0
6	5.5	7.9	10.2	12.2	14.1
7	4.3	6.2	7.9	9.5	11.1
8	3.6	5.1	6.5	7.8	9.1
9	3.0	4.3	5.5	6.7	7.8
SITE INDEX 90					
4	17.4	24.0	29.4	34.1	38.2
5	8.5	12.1	15.3	18.2	20.8
6	5.8	8.4	10.7	12.8	14.7
7	4.5	6.4	8.2	9.9	11.5
8	3.7	5.3	6.7	8.1	9.5
9	3.2	4.5	5.7	6.9	8.1

Table 5.--Expected value growth percents for longleaf pine pulpwood over a 5-year period for intermediate and suppressed crown classes with a top diameter of 3.0 inches inside bark

D.b.h. (inches)	Crown ratio - percent				
	30	40	50	60	70
	- - - - - - Percent - - - - - -				
SITE INDEX 60					
4	--	8.9	16.2	22.1	27.0
5	1.4	5.4	8.9	12.0	14.7
6	1.7	4.3	6.6	8.7	10.7
7	1.8	3.6	5.4	7.0	8.6
8	1.7	3.2	4.6	6.0	7.2
9	1.6	2.9	4.1	5.2	6.3
SITE INDEX 70					
4	1.2	11.0	18.2	24.1	29.0
5	2.1	6.2	9.8	12.9	15.8
6	2.1	4.8	7.1	9.3	11.4
7	2.0	4.0	5.8	7.5	9.1
8	1.9	3.4	4.9	6.3	7.6
9	1.8	3.1	4.3	5.5	6.6
SITE INDEX 80					
4	3.3	13.0	20.2	26.0	30.8
5	2.8	7.0	10.7	13.9	16.8
6	2.5	5.2	7.7	9.9	12.0
7	2.3	4.3	6.2	7.9	9.5
8	2.1	3.7	5.2	6.6	8.0
9	1.9	3.3	4.5	5.7	6.9
SITE INDEX 90					
4	5.2	14.8	21.9	27.7	32.6
5	3.5	7.8	11.5	14.8	17.7
6	2.9	5.7	8.2	10.5	12.6
7	2.6	4.6	6.5	8.3	10.0
8	2.3	3.9	5.4	6.9	8.3
9	2.1	3.4	4.7	6.0	7.1

Table 6.--Expected value growth percents for slash pine pulpwood over a 5-year period for dominant and codominant crown classes with a top diameter of 2.0 inches inside bark

D. b. h. (inches)	Crown ratio - percent		
	30	40	50
	- - - - - Percent - - - - -		
AVERAGE STAND D. B. H. - 2.0 INCHES			
4		26.6	29.0
5		20.5	22.5
AVERAGE STAND D. B. H. - 3.0 INCHES			
4		24.8	27.3
5		19.2	21.3
6		15.1	16.8
7		12.0	13.5
AVERAGE STAND D. B. H. - 4.0 INCHES			
4		22.8	25.5
5		17.9	20.2
6		14.2	16.0
7		11.4	12.9
AVERAGE STAND D. B. H. - 5.0 INCHES			
4	17.6	20.7	
5	14.1	16.6	
6	11.3	13.3	
7	9.1	10.7	
8	7.5	8.8	
AVERAGE STAND D. B. H. - 6.0 INCHES			
4	15.1	18.5	
5	12.6	15.2	
6	10.3	12.3	
7	8.4	10.1	
8	7.0	8.3	
9	5.8	7.0	
AVERAGE STAND D. B. H. - 7.0 INCHES			
6	9.2	11.3	
7	7.7	9.4	
8	6.4	7.9	
9	5.5	6.6	
10	4.7	5.6	
11	4.0	4.9	

Table 7.--Expected value growth percents for slash pine pulpwood over a 5-year period for intermediate crown class with a top diameter of 2.0 inches inside bark

D. b. h. (inches)	Crown ratio - percent		
	30	40	50
	- - - - - Percent - - - - -		
AVERAGE STAND D. B. H. - 2.0 INCHES			
4		23.4	26.1
5		18.3	20.5
6		14.5	16.2
AVERAGE STAND D. B. H. - 3.0 INCHES			
4		21.4	24.2
5		17.0	19.2
6		13.6	15.4
AVERAGE STAND D. B. H. - 4.0 INCHES			
4		19.2	22.2
5		15.6	18.0
6		12.6	14.5
AVERAGE STAND D. B. H. - 5.0 INCHES			
4	13.2	16.8	
5	11.4	14.1	
6	9.5	11.6	
7	7.9	9.6	
AVERAGE STAND D. B. H. - 6.0 INCHES			
4	10.2	14.2	
5	9.7	12.6	
6	8.4	10.6	
7	7.2	8.9	
8	6.1	7.5	
AVERAGE STAND D. B. H. - 7.0 INCHES			
6	7.3	9.6	
7	6.4	8.2	
8	5.6	7.0	
9	4.8	6.0	
10	4.2	5.2	

Table 8.--Expected value growth percents for slash pine pulpwood over a 5-year period for dominant and codominant crown classes with a top diameter of 3.0 inches inside bark

D.b.h. (inches)	Crown ratio - percent		
	30	40	50
	- - - - - Percent - - - - -		
AVERAGE STAND D. B. H. - 2.0 INCHES			
4		34.5	37.3
5		24.0	26.2
AVERAGE STAND D. B. H. - 3.0 INCHES			
4		32.3	35.3
5		22.6	24.9
6		16.9	18.8
7		13.2	14.7
AVERAGE STAND D. B. H. - 4.0 INCHES			
4		29.9	33.1
5		21.2	23.6
6		16.0	17.9
7		12.5	14.1
AVERAGE STAND D. B. H. - 5.0 INCHES			
4	23.4	27.4	
5	16.8	19.6	
6	12.8	15.0	
7	10.1	11.8	
8	8.1	9.6	
AVERAGE STAND D. B. H. - 6.0 INCHES			
4	20.3	24.6	
5	15.0	18.0	
6	11.7	13.9	
7	9.3	11.1	
8	7.6	9.1	
9	6.3	7.5	
AVERAGE STAND D. B. H. - 7.0 INCHES			
6	10.5	12.9	
7	8.5	10.4	
8	7.1	8.5	
9	5.9	7.1	
10	5.0	6.1	
11	4.3	5.2	

Table 9.--Expected value growth percents for slash pine pulpwood over a 5-year period for intermediate crown class with a top diameter of 3.0 inches inside bark

D.b.h. (inches)	Crown ratio - percent		
	30	40	50
	- - - - - Percent - - - - -		
AVERAGE STAND D. B. H. - 2.0 INCHES			
4		30.6	33.7
5		21.5	24.0
6		16.2	18.2
AVERAGE STAND D. B. H. - 3.0 INCHES			
4		28.1	31.5
5		20.0	22.6
6		15.2	17.2
AVERAGE STAND D. B. H. - 4.0 INCHES			
4		25.4	29.1
5		18.4	21.1
6		14.2	16.3
AVERAGE STAND D. B. H. - 5.0 INCHES			
4	17.7	22.4	
5	13.6	16.8	
6	10.8	13.1	
7	8.8	10.6	
AVERAGE STAND D. B. H. - 6.0 INCHES			
4	13.8	19.1	
5	11.7	15.0	
6	9.6	12.0	
7	8.0	9.8	
8	6.7	8.1	
AVERAGE STAND D. B. H. - 7.0 INCHES			
6	8.4	10.9	
7	7.2	9.1	
8	6.1	7.6	
9	5.2	6.5	
10	4.5	5.6	

APPLICATION OF STUDY RESULTS

The use of the results of this study requires a knowledge of the silvicultural characteristics of the species involved. The timber marker must be able to adjust the maturity limits shown in this paper for factors that could not be quantified in this study. Before considering biological and technical limitations of the study results, however, it is useful to consider financial maturity limits, disregarding such considerations.

The initial consideration in making use of these study results is to determine whether conditions on the ground are comparable to the conditions of this study. Once it is decided that the guides presented here can be used, it is necessary that the timber owner specify his alternative rate of return. With this knowledge the timber marker may develop simplified marking guides from the value growth tables (tables 2 to 9). Such guides are developed by comparing the owner's alternative rate of return to the value growth rates and then selecting the type of trees which delimit financial maturity. The timber marker should become familiar with the maturity limits for types of trees likely to be encountered in field practice. For example, in figure 1 the value growth rates for dominant and codominant longleaf pine (2.0-inch merchantable top) growing on land of site index 80 are related to diameter at breast height and crown ratio class. If the forest owner's alternative rate of return is 4 percent (as denoted by the heavy horizontal line) it can be seen

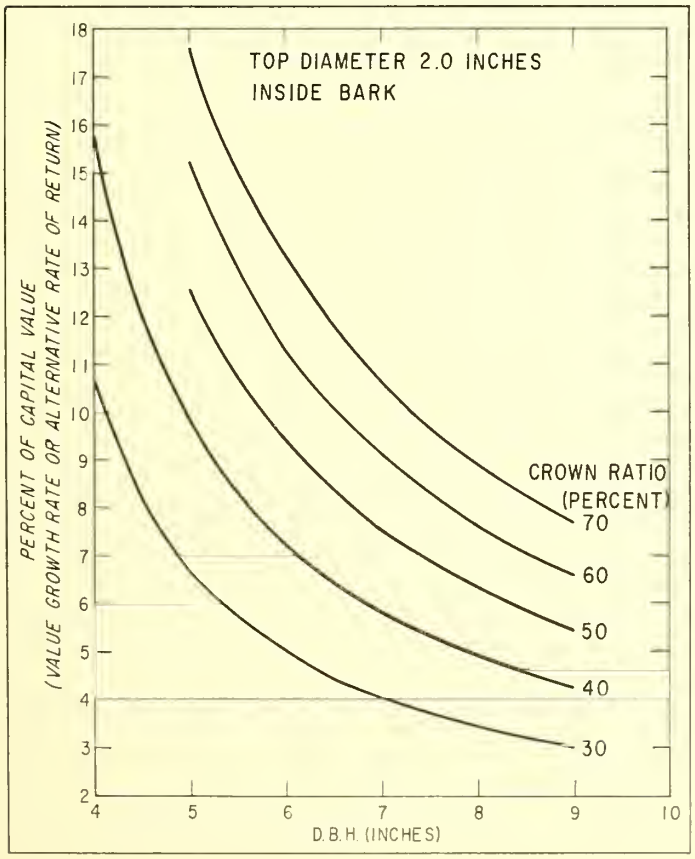

Figure 1.--Value growth rates of dominant and codominant longleaf pine on site index 80 land.

that trees 7 inches d.b.h. and larger would be financially mature if they had a crown ratio of 30 percent or less. If the alternative rate is 6 percent, trees 5.3 inches and larger with 30 percent crown ratio or less, those 6.8 inches and larger with 40 percent crown ratio or less, and trees 8.3 inches and larger with 50 percent crown ratio or less would be mature or overmature.

Slash pine guides are developed in a similar manner. In figure 2 the value growth rates of dominant and codominant slash pine in stands having an average d.b.h. of 6.0 inches are related to d.b.h. of the individual trees and crown ratio class. It is evident that if an alternative rate of 4 percent is applicable, no trees are financially mature within the limits of the data. If an alternative rate of 6 percent applies, trees 8.8 inches d.b.h. and larger with a crown ratio of 30 percent or less are mature.

Maturity limits for intermediate and suppressed trees occur at smaller diameters than for dominant and codominant trees (figures 3 and 4). For longleaf pine, a 4 percent alternative return indicates that all trees with a crown ratio of 30 percent or less and trees 7 inches d.b.h. and larger with a crown ratio of 40 percent and less are mature. In slash pine, a rate of 4 percent would not indicate maturity limits within the range of study results.

From these graphic presentations it is observed that the higher the crown ratio (vigor), and the lower the alternative rate of return, the higher will be the maturity limits defined in terms of tree d.b.h. The timber marker may work out simplified guides directly from the value growth tables and avoid constructing graphs by defining maturity limits in terms of one-inch d.b.h. classes.

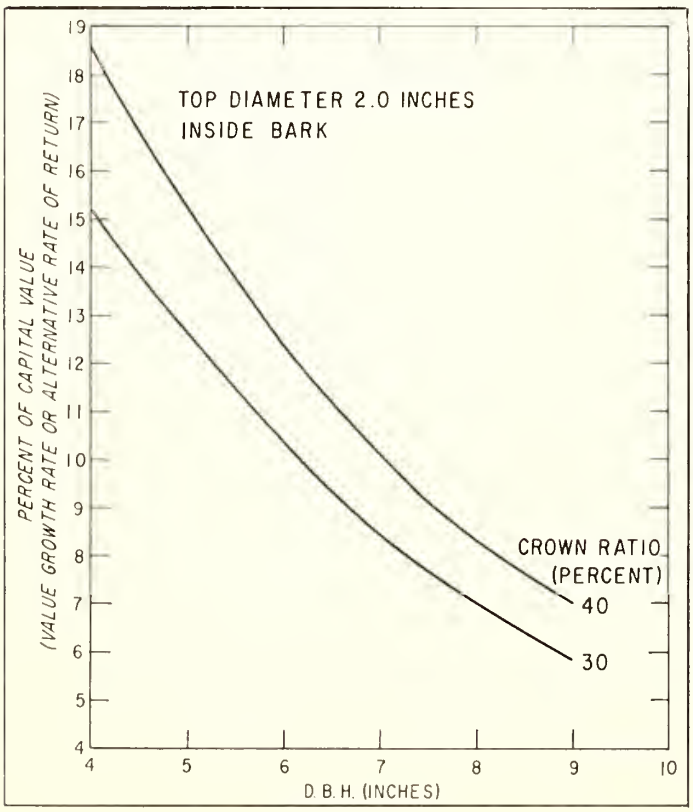

Figure 2.--Value growth rates of dominant and codominant slash pine in stands having an average d.b.h. of 6.0 inches.

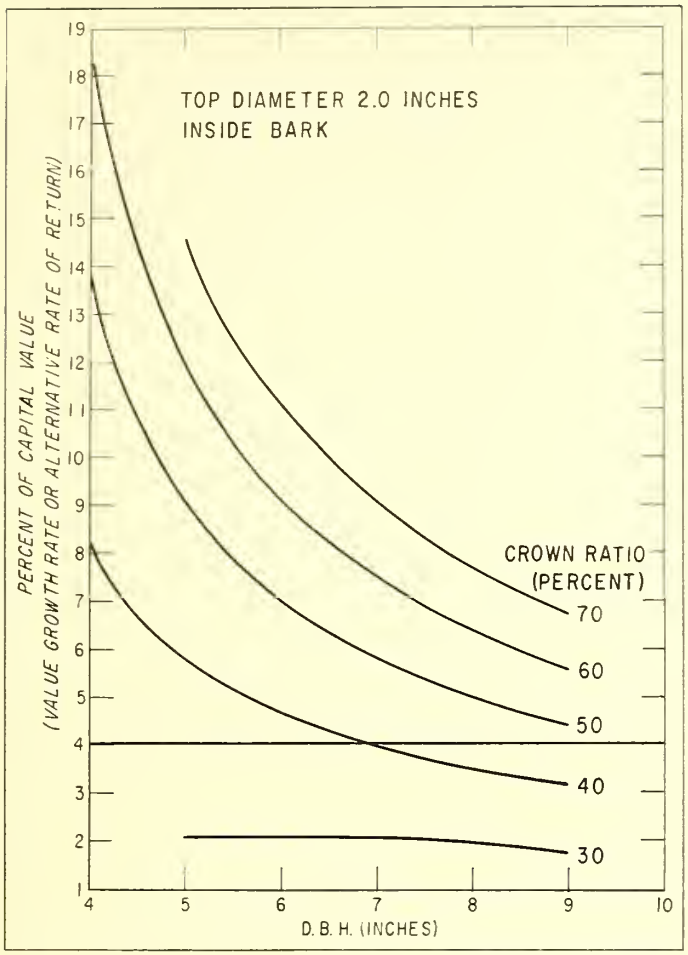

Figure 3.--Value growth rates of intermediate and suppressed longleaf pine on site index 80 land.

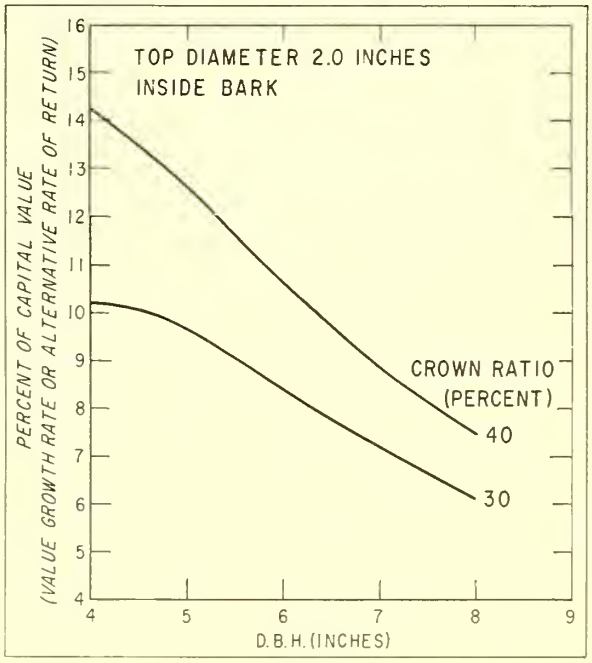

Figure 4.--Value growth rates of intermediate slash pine in stands having an average d.b.h. of 6.0 inches.

From the value growth tables for longleaf pine (tables 2 to 5), it can be seen that the better the site index, other factors being equal, the higher will be the predicted maturity limits. For example, with a 2-inch top limit, if an alternative rate of return of 6 percent applies and dominant and codominant trees with a crown ratio of 40 percent are considered, the maturity limits for site index classes 60, 70, and 80 would be the 7-inch d.b.h. class; but for site index 90 the limit would be the 8-inch diameter class (see table 2). All trees equal and larger in diameter than the maturity limit should be cut and the capital represented by such trees invested in alternatives yielding at or above the alternative rate of return.

Use of the slash pine value growth tables (tables 6 to 9) requires an estimate of average stand d.b.h. based on all trees one inch and larger in diameter before simplified marking guides can be constructed. The value growth rate decreases as average stand d.b.h. increases. Simplified marking guides may be constructed in the usual manner once average stand d.b.h. is estimated.

It is important to keep in mind that the guides presented here refer only to a single product, pulpwood. This restriction means that if a tree is expected to qualify as sawtimber or some other higher value product after a 5-year growth period, the value growth percents presented here are not applicable. The results of this study apply only to cases where the owner sells pulpwood on the stump.

It is necessary that the timber marker consider the effect of removing a given tree on the growth and development of nearby residual trees. These factors cannot be adequately quantified to be included in the financial maturity calculations, and must be judged by the timber marker on the basis of his experience before the marking decision is finally made. Silvicultural experience must be called upon when a group of competing trees earning just below the alternative rate of return is considered. Blindly following the value growth tables would indicate the entire group ready for harvest. The marker should, on the basis of his silvicultural knowledge of the species, estimate the increase in growth rate of residual trees which would result if one or more of the trees is removed. A more complete discussion of the need for tempering financial maturity guides with silvicultural knowledge may be found in Technical Bulletin 1146 by Duerr, Fedkiw, and Guttenberg.

The guides presented in this paper should be applied to thinning operations in even-aged longleaf and slash pine stands. The time at which the thinning is applied depends on factors independent of the financial maturity of the trees within the stands. There must be, of course, an adequate volume removed to justify a cutting operation. Insect and disease problems must be considered in timing thinnings if increased mortality is to be avoided. Market conditions must be analyzed to time cuts during a period when stumpage prices are to the owner's advantage. These and all other factors which normally enter into a decision concerning commercial thinning must be considered whether financial maturity guides are used or not. Financial maturity guides simply quantify certain factors, leaving fewer factors that must be considered in a subjective manner.

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